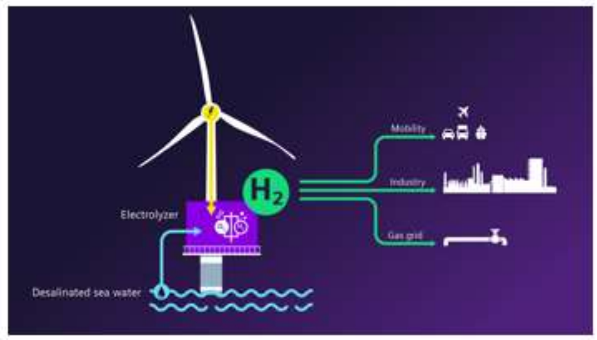
Levelized Cost (LC) of Repurposing Offshore Infrastructure for Clean Energy (ROICE) Projects in the Gulf of Mexico

Courtesy: Endeavor Management



Courtesy: Siemens Gamesa

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November 2023

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This project was paid for [in part] with federal funding from the Department of the Treasury through the State of Texas under the Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act of 2012 (RESTORE Act). The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the State of Texas or the Department of the Treasury.

Executive Summary

As the 1500 plus oil & gas structures in the US Gulf of Mexico (GOM) reach the end of their oil & gas phase, these structures as well as the thousands of miles of pipelines have the potential to be converted into ROICE (Repurposing Offshore Infrastructure for Clean Energy) projects. Repurposing is the re-use of some or all the existing infrastructure for a new project.

A comprehensive model has been developed for estimating levelized costs (LC) for such projects. The ROICE LC Model can estimate LCs for wind power and hydrogen generation for both new build projects and projects that repurpose some of the existing oil & gas infrastructure.

Using this model, Geospatial Levelized Cost Maps (GSLCMaps) have been generated that show LC distributions for different project scenarios across the GOM. These GSLCMaps have been analyzed to identify favorable locations for ROICE projects, how they compare with onshore and other alternatives, and to understand the impact of various key variables and cost elements on LC.

Key conclusions from Phase 1 of this study are as follows:

- LCs for repurposed wind projects in the GOM range from $82 to $231 per MWh. Equivalent new build projects have LC's ranging from $82 to $437. LC's for repurposed hydrogen projects in the GOM range from $4.76 to $8.44 per kg of hydrogen. Equivalent new build projects have LC's ranging from $4.77 to $19.64.
- While noting that the above LC's do not include any federal or state incentives, these are higher than equivalent low-carbon renewables-based onshore projects, and even more challenged versus high-carbon alternatives.
- However, projects at the lower end of the range of LC's across the GOM have the potential to be competitive with onshore projects through efficient design, cost reductions and use of all available federal and state incentives.
- Of the different components of the oil & gas structure to be repurposed, it is probably most cost-effective to reuse the jacket (main support structure) and the deck (flooring above the structure) for ROICE projects. Pipelines can also be re-used to bring hydrogen back to shore. The remaining equipment will need to be decommissioned as per normal practice - removal of oil & gas topsides, abandonment of all wells and any pipelines that will not be used to transport hydrogen.
- Repurposing reduces Capital Cost (CAPEX) and shortens the schedule of implementation of ROICE projects. and has a positive impact on LC for most projects. This improvement is more pronounced for deeper water projects and for smaller scale projects where the savings from reused infrastructure form a significant portion of the total project CAPEX - 5 - 10% for near shore locations and 25 – 60% for deepwater projects.
- It is advantageous to consider repurposing options for deeper water / further from shore projects. Of course, these projects are challenged with high LC's even after repurposing, so further optimization and greater production incentives are needed to make these projects attractive.
- CAPEX for hydrogen projects is in the range of +/- 10% of power project CAPEX. The incremental economics on the additional CAPEX for hydrogen generation is therefore likely to look quite promising in all cases, especially considering the healthier federal incentives for hydrogen production vs wind power generation.

Repurposing and ROICE Projects

Over the last 75 years, roughly 7,000 platforms have been installed in the Gulf of Mexico (GOM). Additionally, the GOM infrastructure includes 14,000 wells and 10,000 miles of pipelines (Figure 1). These assets, once they reach the end of their fossil energy purpose, are "decommissioned," usually meaning plugged and abandoned (wells), removed or preserved in place (pipelines), taken apart and brought back to shore, or sunk to the ocean floor (platforms and structures).

A sizeable fraction of this infrastructure can be reused for clean energy projects given the right structural and geospatial conditions, technology improvements and federal and state incentives. Platforms and other structures can be used to support equipment for wind energy and hydrogen generation, pipelines can be used to bring hydrogen to shore. These ROICE projects can extend the life of installed infrastructure, reduce carbon footprint vs new build, and generate clean energy jobs and revenue. Further, several studies have shown that these offshore structures become ecologically important artificial reefs and positively alter the ecosystem around these platforms (van Elden et al., 2019). Through ROICE projects, this positive impact can continue to be available for an additional decade or two.

The Figure 2 shows wind speed distribution across the Gulf of Mexico ranges from 7 to 9 meters/second (Musial et al. 2020). These speeds are lower than in other geographical areas such as the US Atlantic Coast (7.4 to 9.3 m/s) (Peevey & Lenoir, 2022) and the UK North Sea (8 to 14 m/s) (Hahmann et al., 2022). However, additional advantages of the Texas Gulf Coast include:

- Offshore wind speeds are higher and more consistent than onshore winds, which helps to maximize electrical power per acre and potentially reduces the operational challenges of onshore wind intermittency.
- Global demand for hydrogen is expected to grow 5 to 8-fold by 2050 (Global Hydrogen Review 2021)
- Ready access to seawater as green hydrogen feedstock material, thus avoiding competing with existing demand for already limited freshwater supplies in the region.
- Hydrogen can be stored in large quantities for long durations onshore or offshore in subsurface salt caverns, depleted oil and gas reservoirs, or in deep saline aquifers. Hydrogen storage in oil and gas reservoirs would of course require processing when produced to separate it from any produced oil or gas
- The Gulf Coast onshore is home to a globally premier hydrogen system, including extensive production, transportation, and storage assets. Hydrogen production on the Gulf Coast amounts to 3.5 million metric tons per year, and the region also has more than 1,000 miles of hydrogen pipelines (Chevron, 2023).

By harnessing these advantages, leveraging the extensive oil and gas infrastructure for repurposing, and leveraging learnings from ongoing projects elsewhere in the world, the US GOM can be positioned to be ready with profitable ROICE projects.

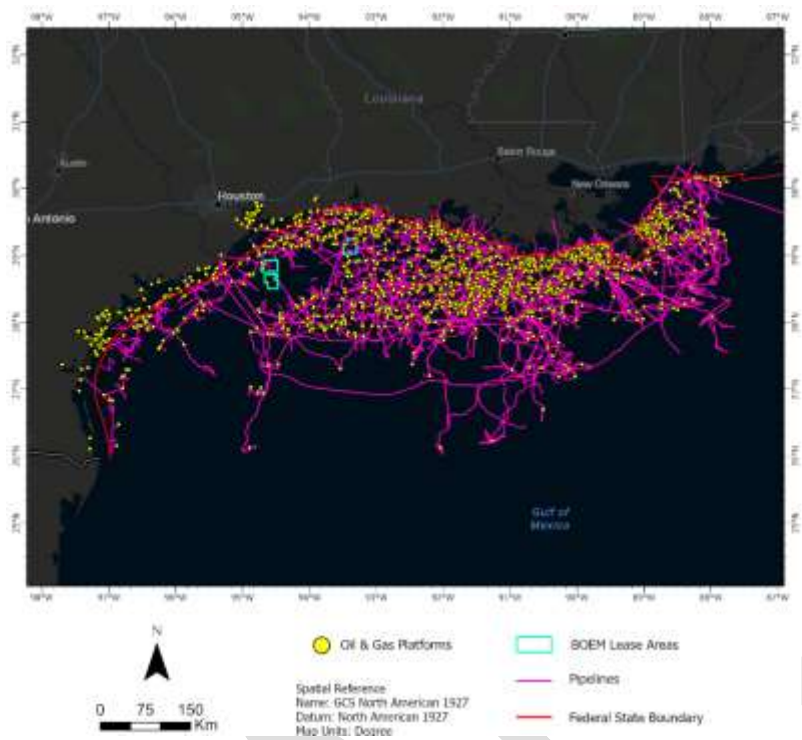

Figure 1: Oil and Gas Platforms, BOEM Lease Areas, Pipelines in the Gulf of Mexico

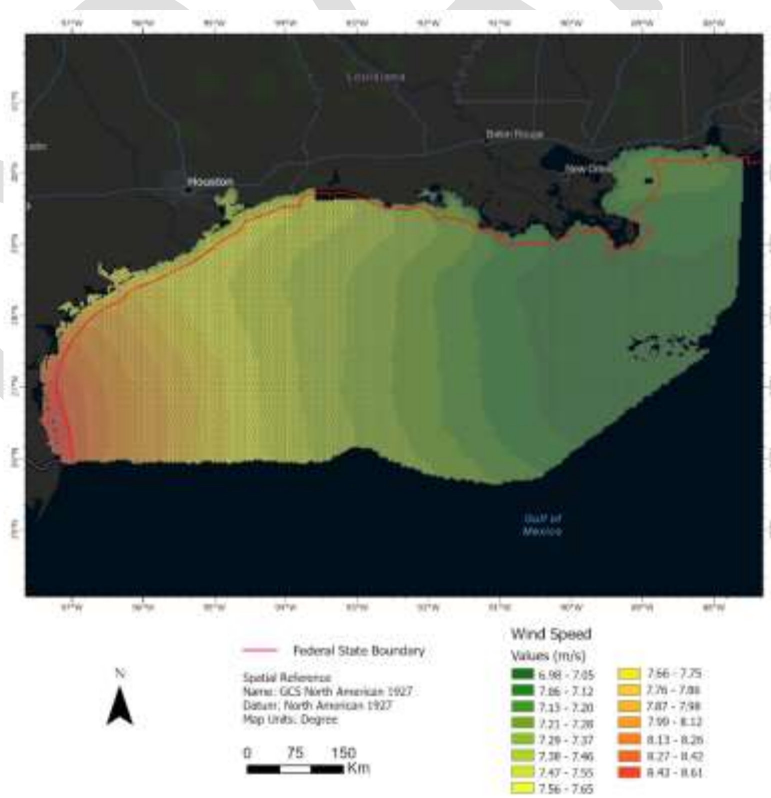

Figure 2: Average Wind Speed along the Gulf of Mexico

UH Energy ROICE Initiatives

To realize this potential, many challenges facing such ROICE projects will need to be addressed. A key one is project economics. Along with the well-known challenge of the levelized cost differential between low-carbon electric power and the current fossil-based power generation, and between low-carbon hydrogen and current industrial hydrogen, moving the systems offshore adds additional costs.

Other technical challenges include ensuring structural integrity and remaining life of the offshore installations (for repurposing projects), reducing the costs of large-scale electrolysis and wind power through economies of scale, finding other cost reductions such as saline water electrolysis technologies, repurposing hydrocarbon pipelines for hydrogen transportation etc. In addition, the regulatory framework, commercial and liability considerations, and public acceptance aspects need to be addressed.

To address these challenges and develop a comprehensive framework for ROICE projects in the US GOM, the UH Energy program at the University of Houston launched the ROICE program with two key initiatives (Figure 3). The first of these is Project SHOWPLACE (Storing Hydrogen from Offshore Wind Power for Load-balancing and Carbon Elimination), which will establish the techno-economic feasibility of a subset of ROICE projects that bring together three components – repurposing existing offshore infrastructure, harnessing wind energy and generating hydrogen from sea water.

The second initiative is ROICE Workgroups. This initiative consists of a set of seven workgroups that will develop the ROICE Project Implementation Framework (PIF), covering regulatory, commercial, and technical considerations that need to be put in place to make ROICE projects successful. These workgroups are made up of key stakeholders from industry, academia, and policy groups. They will develop a set of white papers that are expected to be valuable reference materials as commercial ROICE projects move forward. ROICE results will be reported elsewhere. This report focuses solely on results from Phase 1 of SHOWPLACE.

Figure 3: UH Energy ROICE Initiatives

The basic ROICE concept is to install a set of floating or fixed Wind Turbine Generator (WTG) around a repurposed offshore platform. The resulting power is either transmitted back to shore as electric power or used for to produce hydrogen by desalinating seawater, electrolyzing the resulting fresh water into hydrogen and oxygen, and transporting the hydrogen via existing pipelines to shore. In a power project, the offshore structure is used to house power transmission infrastructures such as converters, substations, and supporting infrastructure. In a hydrogen project, the offshore structure will also house desalination units, electrolyzers, and other balance of plant.

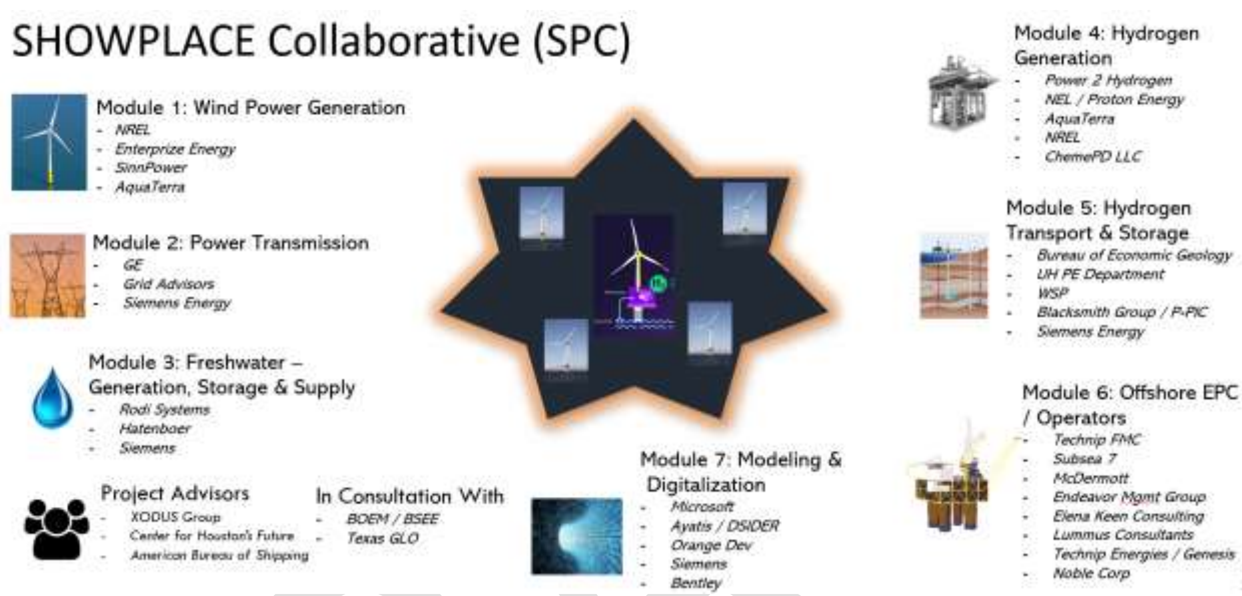

Figure 4: The SHOWPLACE Collaborative

As shown in Figure 4 above, this concept is divided into seven modules, ranging from power generation, transmission, hydrogen generation, storage, and offshore infrastructure repurposing to digital twin modeling. Each module is advised by key experts drawn from the industry, national labs, and academia, listed in the figure above. They form the SHOWPLACE Collaborative or SPC. In addition, regulatory bodies such as BOEM and BSEE are frequently consulted and kept informed. SPC Members provide critical consultation on equipment design, costs, and installation methodology, and they review and approve the model and results.

The ROICE LC Model

In this study, the levelized costs of energy (LCOE) and hydrogen (LCOH) were examined. Several models exist in the literature indicating the lack of a standard definition for LCOE and LCOH. Short, et al. (1995) computed the LCOE with Equation 1 as follows:

$$LCOE = \frac{TLCC}{\sum_{n=1}^{N} \frac{Q_n}{(1+d)^n}}$$

Equation 1

Where LCOE = levelized cost of energy; TLCC = total life-cycle cost; Q_n = energy output or saved in year n; d = discount rate; N = analysis period.

TLCC is computed as follows:

$$TLCC = \sum_{n=0}^{N} \frac{C_n}{(1+d)^n}$$

Equation 2

Where C_n = cost in period n.

Investment costs include finance charges as appropriate, expected salvage value, nonfuel O&M and repair costs, replacement costs, and energy costs;

For a given location in the GOM, levelized costs were estimated for power generation and hydrogen generation, repurposed and new build versions, small scale, and large-scale projects. The resulting eight case matrix is shown below in Table 1.

Table 1: Case Nomenclature

Product	Capacity	Repurposing	New Build
Power	435 MW	E500R	E500N
	105 MW	E100R	E100N
Hydrogen	435 MW (180 MW Electrolyzer Capacity)	H500R	H500N
	105 MW (40 MW Electrolyzer Capacity)	H100R	H100N

Detailed CAPEX and Operating Cost (OPEX) estimates were developed for all eight cases. In all the H_2 generation cases, the power input is assumed to come from a newly installed wind turbine generator (WTG) system. All the power generated by the WTG system is assumed to be used for H_2 generation. The cost of this power generation is thus included in the LCOH calculation as CAPEX (as opposed to other projects where the power is obtained from the grid and is therefore OPEX). The power generation capex is lower than equivalent power export projects since it excludes costs of export cables and the onshore substation since power is not being exported to shore in these cases.

For the repurposing cases, different options for repurposing were evaluated. It was concluded that the most cost-effective option was to reuse the jacket (main support structure) and the deck (flooring above the structure) for ROICE projects. Pipelines can also be re-used to bring hydrogen back to shore. The remaining equipment will need to be decommissioned as per normal practice – removal of oil & gas topsides, abandonment of all wells and any pipelines that will not be used to transport hydrogen.

CAPEX estimates are shown below for a typical shallow water / near-shore location in Table 3 and Table 3 and a typical deepwater / far from shore location are shown in Table 4 and Table 5, for the eight cases shown in the above Table 1.

Table 2: Major CAPEX breakdown for a typical shallow water: Power export project; All Costs in M$

Major CAPEX Components	E100N	E100R	E500N	E500R
WTG costs	195.3	195.3	809.1	809.1
Structural costs (Foundations and Installations)	43.4	34.2	146.7	137.6
Cables	151.1	151.1	182.1	182.1
On-Shore Substation	2.0	2.0	4.2	4.2
Off-Shore Substation	3.8	3.8	15.8	15.8
Project Development Fixed costs	97.6	97.6	404.2	404.2
Total CAPEX	493.2	484.0	1562.2	1553.0

Table 3: Major CAPEX breakdown for a typical shallow water hydrogen export project; All Costs in M$

Major CAPEX Components	H100N	H100R	H500N	H500R
Electrolyzer	48.0	48.0	216.0	216.0
Structural costs (Foundations and Installations)	10.5	1.3	10.5	1.3
Onshore Compression	3.9	3.9	14.6	14.6
Desalination	1.2	1.2	3.4	3.4
Pipeline	74.8	26.2	74.8	26.2
Power Generation	339.0	339.0	1404.2	1404.2
Project Development costs	3.2	2.7	12.2	11.8
Total CAPEX	484.3	423.5	1,739.4	1,678.7

Table 4: Major CAPEX breakdown for a typical deepwater power export project; All Costs in M$

Major CAPEX Components	E100N	E100R	E500N	E500R
WTG costs	195.3	195.3	809.1	809.1
Structural costs (Foundations and Installations)	251.4	90.1	527.4	366.2
Cables	283.7	283.7	332.8	332.8
On-Shore Substation	19.1	19.1	79.0	79.0
Off-Shore Substation	22.9	22.9	94.8	94.8
Project Development Fixed costs	97.6	97.6	404.2	404.2
Total CAPEX	869.9	708.6	2,247.3	2,086.1

Table 5: Major CAPEX breakdown for a typical deepwater hydrogen export Project; All Costs in M$

Major CAPEX Components	H100N	H100R	H500N	H500R
Electrolyzer	48.0	48.0	216.0	216.0
Structural costs (Foundations and Installations)	163.5	2.3	163.5	2.3

Onshore Compression	3.4	3.4	12.7	12.7
Desalination	1.2	1.2	3.4	3.4
Pipeline	323.1	113.1	323.1	113.1
Power Generation	415.7	415.7	1731.5	1731.5
Project Development costs	10.8	2.7	19.8	11.7
Total CAPEX	981.8	592.0	2,486.3	2,096.5

A few comments on the above table of CAPEX estimates:

- Turbine (WTG) costs scale according to the size of the project since scale up is assumed to be simply an increase in the number of turbines (7 x 15 MW turbines for a 105 MW project, 29 x 15 MW turbines for a 435 MW project). No reduction in unit turbine costs is assumed in this screening study for a larger installation.
- Pipeline costs are the same for different scales since we have assumed an oversized 14-inch pipeline for either case. This assumption was made based on PipeSIM simulations, to identify a size which results in negligible pressure drop for H2 export. This allows compression to be moved onshore and reduces the risk of hydrogen embrittlement and leakage. Onshore compressions costs are then purely a function of hydrogen flow rate, which varies from location to location due to differences in wind speed. Offshore substation and Onshore Substation costs for deeper water installation are higher due to the use of HVDC transmission type which is necessary for any installation beyond 100 km. HVDC systems entail a substantially higher cost.
- Structural costs have been assumed to be independent of scale. For a new build case, this is a simplifying assumption for screening purposes given that structure costs are not a large fraction of the total costs. For a repurposing case, typical oil and gas platforms house much larger and heavier topsides than is needed for equipment for wind or hydrogen projects. So costs are minimal.

The impact of repurposing on project CAPEX for different project configurations is shown in the Table 6.

Table 6 : % CAPEX ratios for Repurposing Projects

CAPEX Ratios: Repurposing Capex / New Build Capex

Power	Shallow	Deep
435 MW	99%	93%
105 MW	98%	81%

Hydrogen	Shallow	Deep
435 MW	97%	85%
105 MW	88%	61%

Conclusions from the above analysis are as follows:

- The impact of repurposing increases with water depth (with a corresponding influence of distance to shore) and for smaller projects. This can be attributed to higher structural costs avoidance in deeper waters from reusing existing structures

- Repurposing has a greater impact on hydrogen projects from the reuse of pipelines to bring hydrogen to shore.

Table 7 compares CAPEX outlay for power projects and the equivalent power to hydrogen projects.

Table 7: Hydrogen CAPEX compared to Power CAPEX

Hydrogen CAPEX vs Power CAPEX		
Repurposed	Shallow	Deep
435 MW	108%	100%
105 MW	87%	83%
New Build	Shallow	Deep
435 MW	111%	110%
105 MW	97%	111%

There are some interesting conclusions that can be drawn from the above analysis:

- The above figures represent a tradeoff between export cables and offshore substation for a power project vs. avoiding those costs and instead incurring the costs of the hydrogen generation components.
- When this tradeoff is compared for the cases above, it is clear that minimal additional CAPEX is needed to export hydrogen vs power. In some cases, especially for repurposed small-scale projects, the tradeoff results in a CAPEX reduction.
- The incremental economics on the additional CAPEX for hydrogen generation is likely to look quite promising in all cases, especially considering the healthier federal incentives for hydrogen production vs wind power generation.

LC GSLCMaps for the US GOM – Power Export Cases

The ROICE LC model enabled calculation of the LC for any given point in the Gulf of Mexico, when combined with geospatial attributes such as bathymetry, wind speeds, distance to shore etc. An Iterative Geospatial Algorithm was then used to generate LC values and LC "GSLCMaps" across the entire US GOM for all eight ROICE cases.

From this mapping exercise, LC values were found to be a complex function of several variables:

- Wind speeds at the location determines power generation and hydrogen generation levels. Average wind speeds are higher for western GOM locations and close to shore.
- Project size dictates the size and cost of power and hydrogen generation equipment installed and supported. Most of the costs scale with the size of the projects with the notable exception of power export cables and pipelines for hydrogen export.
- Water depths determine structural foundation type and costs for the wind turbines and the platform hosting the support infrastructure for power and hydrogen generation

– Distance to shore determines the length and cost of power export cables, length of pipeline to be repurposed or newly installed for hydrogen. It also influences offshore substation costs due to the transition from HVAC transmission type near shore to HVDC further away from shore.
– Repurposing has an impact on structural costs through the reuse of existing oil & gas structures to house electrical support equipment and hydrogen generation equipment. New build projects will have to incur the cost of a new platform. Repurposing pipelines also has an impact on CAPEX, avoiding the cost of a newly installed pipeline.

In addition, some variables have secondary influences:

– Water depth dictates the type of installation and maintenance vessels to be used
– Distance to shore, specifically distance to installation ports and O&M ports and power grid tie points, determines vessel days required for installation and maintenance

Figure 5 (a-d) compares all four power export cases from this study on a common scale, enabling comparison and seeing the impact of project scale and comparing new build and repurposing cases. A few observations from this comparison: LC's for projects near shore, in shallow waters are better than those in deeper waters; large scale projects are more economic, and repurposing has a greater impact on projects in deeper waters and on smaller scale projects.

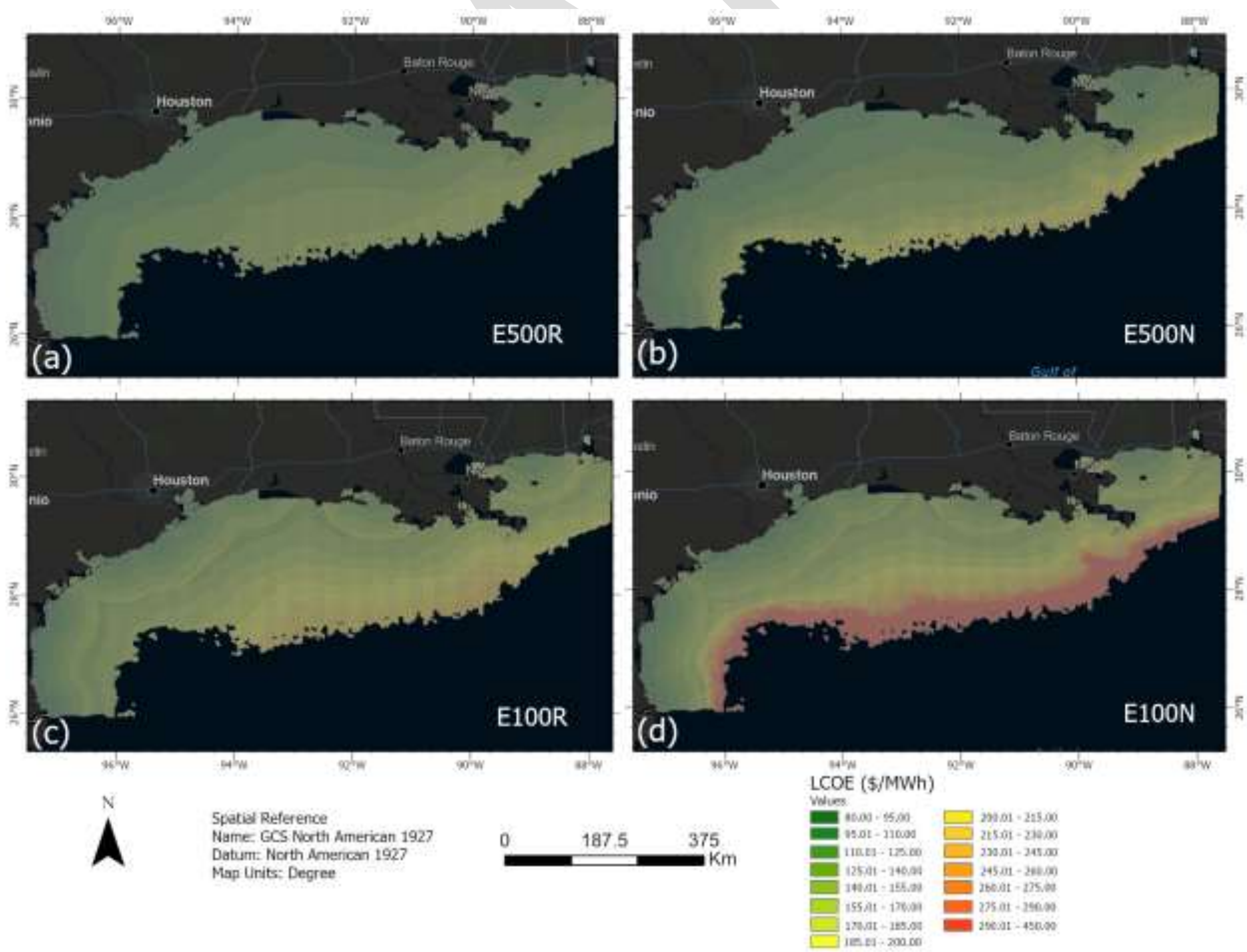

Figure 5: Four Power Export Cases on a common scale (a) E500R (b) E500N (c) E100R (d) E100N

The LCOE GSLCMaps for E500R (Power Export, 435 MW Size, Repurposed) is shown in Figure 6. The levelized cost ranges from $81.97 to $168.23/ Megawatt-hour (MWh). The LCOE GSLCMaps for E100R (Power Export, 105 MW, Repurposed) is shown in Figure 7. LC's range from $86 to $231/MWh for this case. As expected, economies of scale help keep the costs down for the larger project, especially at the higher end. In both these cases, as can be seen from the color shading in these GSLCMaps, locations closer to shore in shallow waters have lower costs. The lower end of the LCOE ranges above thus correspond to near-shore shallow water locations while the higher end are locations farther from shore in deeper water. This is primarily driven by the higher costs for floating turbines and longer cable lengths to bring the power to shore. A secondary contributor is higher installation and maintenance costs for locations further from shore and in deeper water, requiring more complex service vessels.

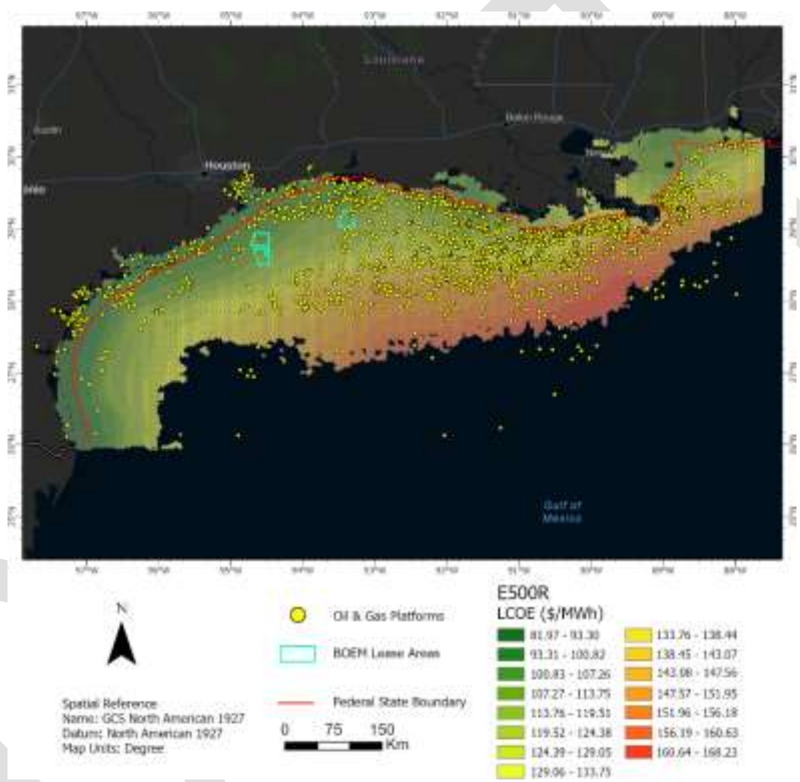

Figure 6: LCOE for power export E500R

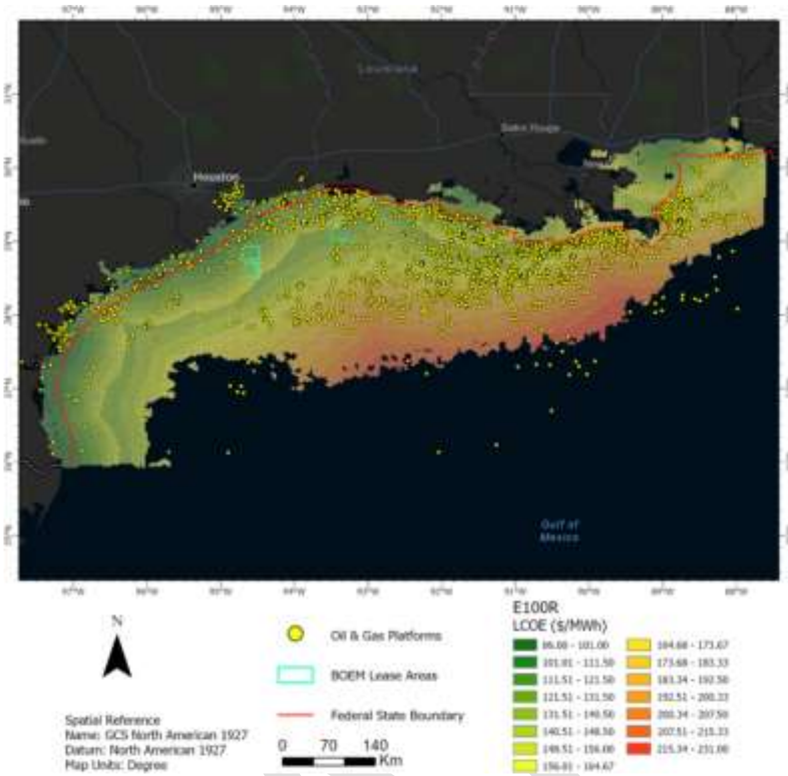

Figure 7: LCOE for power export E100R

LC for the equivalent new build case E500N case ranges from $82.06 to $220.26/MWh, while those for E100N case ranges from $86.14 to $436.78/MWh. As can be seen from a comparison of these LC ranges, repurposing provides a greater LC reduction at the higher end of the range (deeper waters and/or further from shore). This is primarily driven by the cost of the OSS foundation jacket which becomes more expensive as the water depth increases. Repurposing also has a greater impact on the levelized costs for smaller projects, since the savings from reusing the jacket is a larger fraction of the total cost.

Figure 8 compares the LCOE range for the four power export cases in this study to onshore wind and solar photovoltaic (PV) with and without production and investment tax credits (PTC and ITC), with or without storage, and at utility scale or not. The lighter colored bars on the right for each of the project LCOE cases represent cases in water depths greater than 400 m.

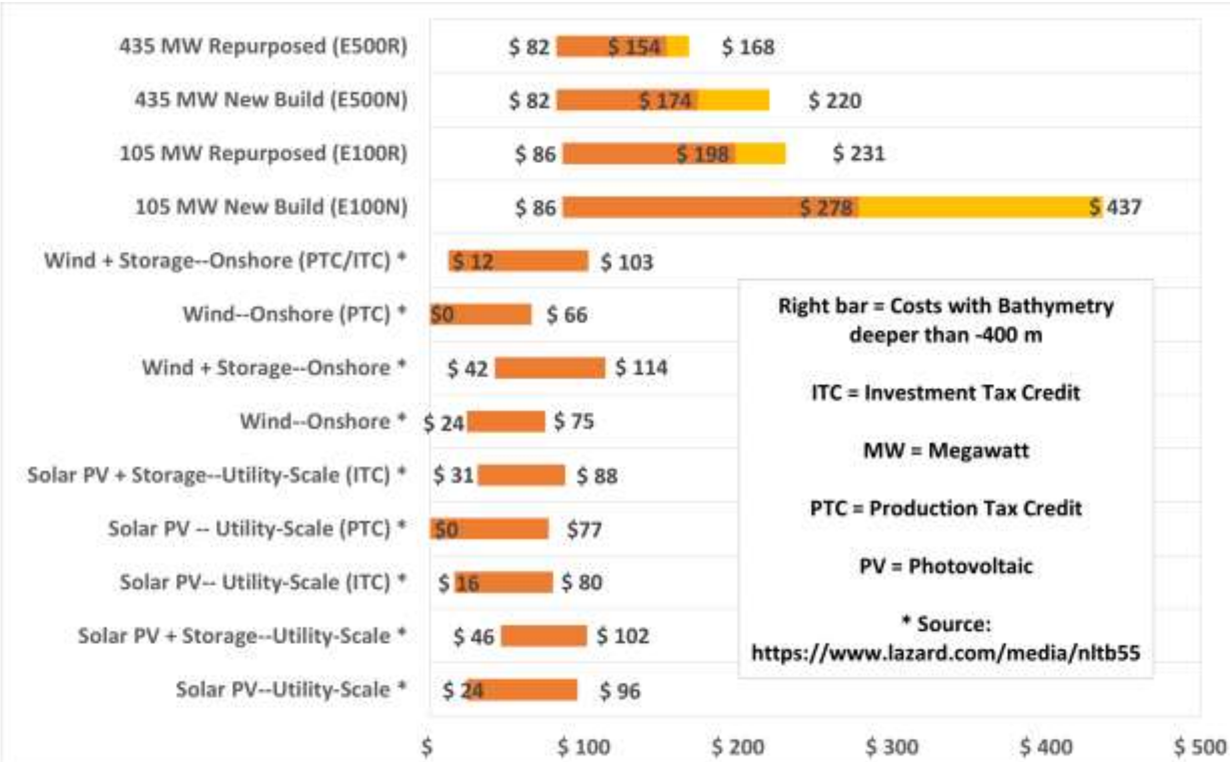

Figure 8: Levelized Cost of Electricity ($/ MWh) (Lazard, 2023)

Key conclusions to draw from this comparison are as follows:

- As expected, the range of LC for offshore renewable projects is higher than onshore renewables.
- Smaller scale projects need to be in shallow water / near-shore locations to be economic
- Repurposing helps reduce the LC for deeper water and/or far-shore locations
- Repurposing has a greater impact on small scale projects
- In several regions where repurposing does have a tangible impact, the overall LC is high even with repurposing, indicating challenging project economics

However, it should be pointed out that these LC's do not account for any federal credits such as ITC or PTC for renewables. It should also be pointed out that these are screening level estimates with generalized assumptions. More definitive conclusions will be expected to be drawn in future phases of this work where ROICE designs will be developed for specific assets with more accurate cost estimates and include all applicable credits to estimate more accurate project economics.

LC GSLCMaps for the US GOM - Hydrogen Export Cases

The Levelized Cost of Hydrogen (LCOH) GSLCMaps allow for comparison of screening level cost of producing hydrogen at various locations in the Gulf of Mexico. As discussed above, these LCOH cases are powered by the appropriate size of wind power generation systems. The "H100" cases thus are supported by a 105 MW wind power generation system identical to the equivalent "E100" case, without, of course, the need for export cables. The "H500" cases are supported by 435 MW wind power generation systems identical to those in the equivalent "E500" cases.

Figure 9 (a-d) compares all four Hydrogen Export Cases on a common scale, enabling comparison and seeing the impact of project scale and comparing new build and repurposing cases. Similar to the comparison of the power export cases above, a few observations can be made from this comparison: LCs for projects near shore, in shallow waters are better than those in deeper waters; large scale projects are more economic, and repurposing has a greater impact on projects in deeper waters and on smaller scale projects.

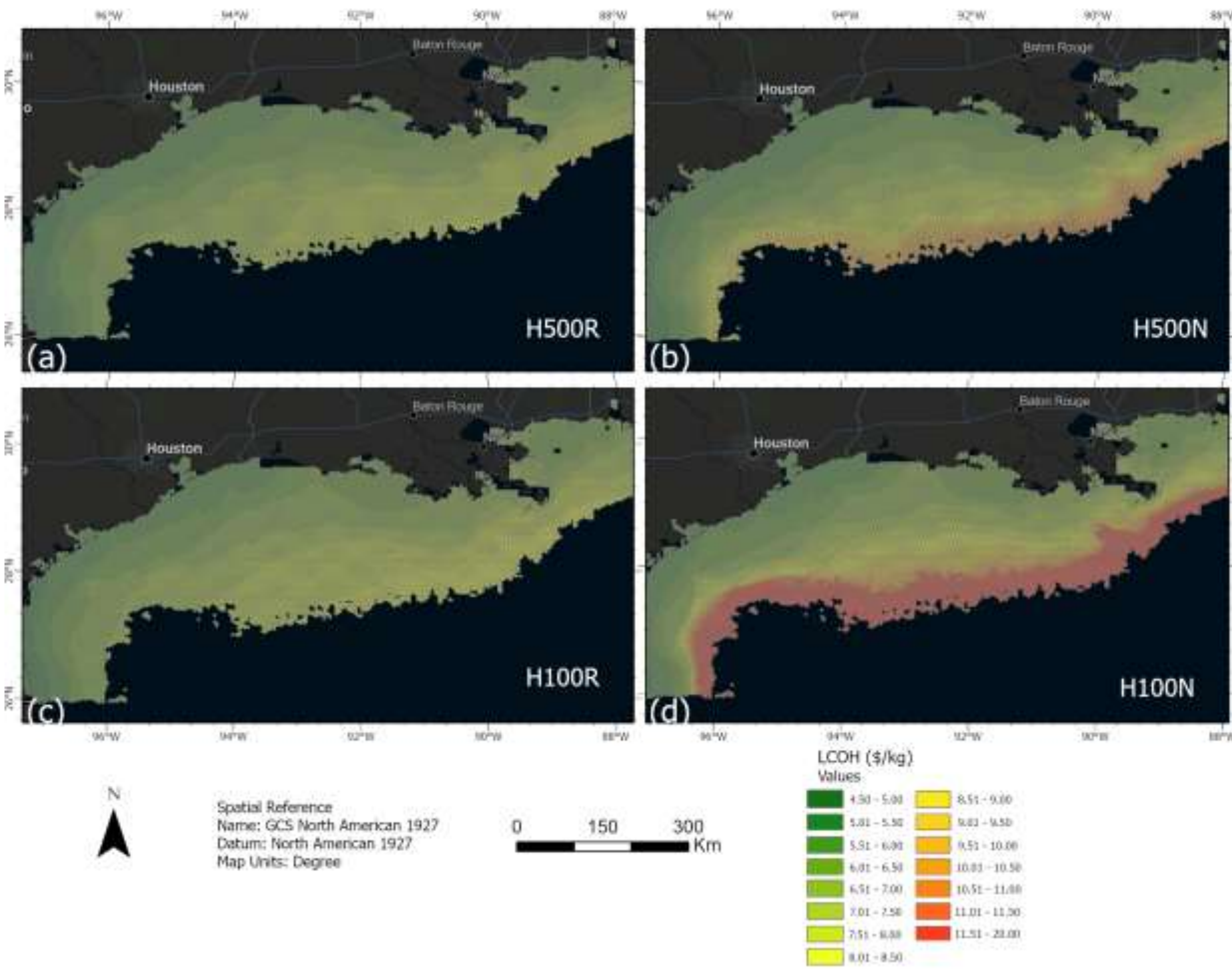

Figure 9: Four Hydrogen Export Cases on a common scale (a) H500R (b) H500N (c) H100R (d) H100N

The LCOH GSLCMaps for the H500R case (Hydrogen export, 435 MW size, Repurposed) is shown in Figure 10. The LC for this case ranges from 4.76 to $8.21/kg. The equivalent chart for a demonstration scale project H100R (Hydrogen export, 105 MW Size, Repurposed) is shown in Figure 11. LC's for this case range from 4.91 to $8.44/kg. In both these cases, the lower end of the LCOH ranges above correspond to near-shore and shallow water locations while the higher end are locations are further from shore in deeper water. This is primarily driven by the higher cost for floating wind turbines, and higher pipeline repurposing costs due to a greater distance from shore. A secondary contributor is higher installation and maintenance costs for locations further from shore and in deeper water, requiring more complex service vessels.

However, unlike in the power export cases, hydrogen projects do not have significant economies of scale. The LC for H100R is only 3% higher than that of H500R, across the entire range of LC's. This implies that a large fraction of costs for a hydrogen project scale linearly with project size. Said another way, in power projects, the cost of export cables does not scale according to the power being exported via these cables. These come in set sizes as described earlier in this report. Therefore, higher capacity projects result in lower LC values by sending more power through the same cost of cables. The scale effect for hydrogen projects is further diluted because they have the option to repurpose pipelines at a cheaper cost than laying new export cables in a repurposed electricity project.

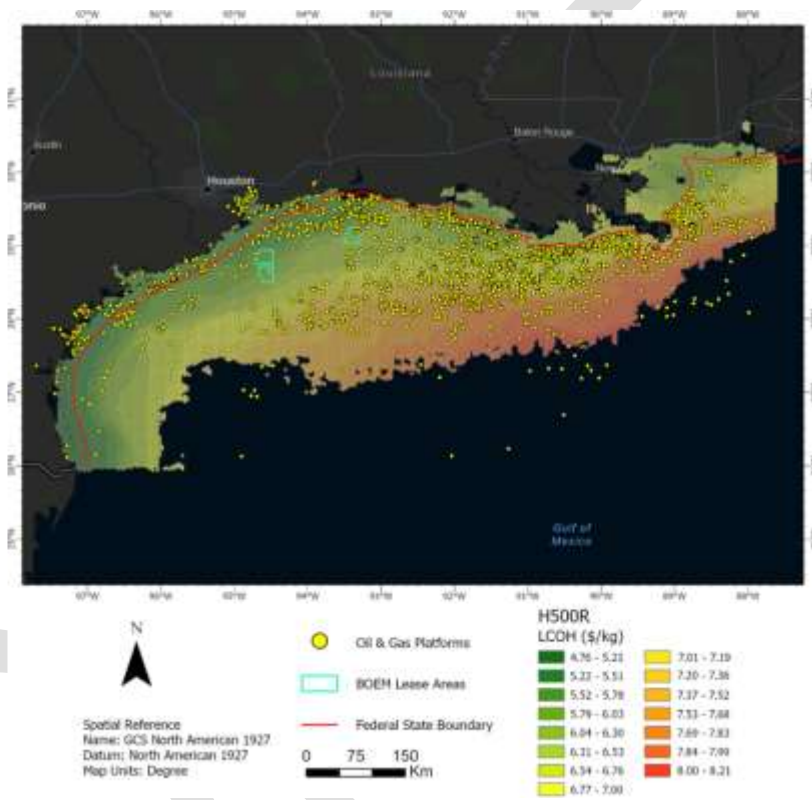

Figure 10: LCOH for power export H500R

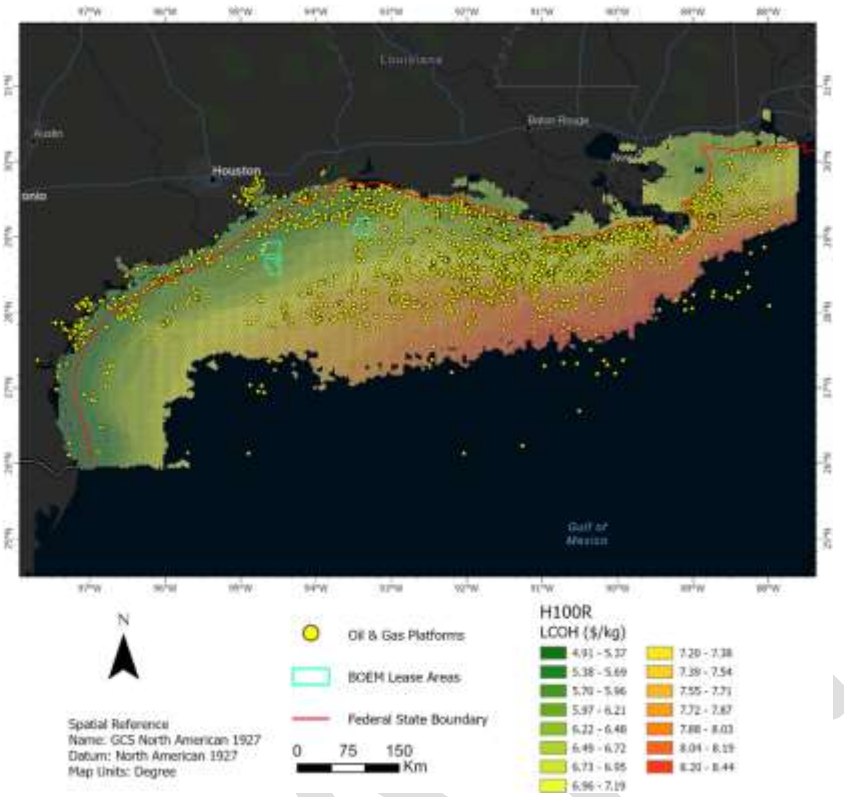

Figure 11: LCOH for power export H100R

The LC GSLCMaps for the equivalent new build cases have also been estimated. LC's for H500N range from 4.77 to $10.81/kg, while those for H100N range from $4.91 to $19.64/kg. As in the Power Export cases, repurposing reduces the LC at the higher end of these ranges (deeper water and/or further from shore). Again, this is because new build projects need to install a new foundation and structure to support the hydrogen generation components, the cost of which can be quite significant in deeper waters. Repurposing cases avoid this cost by reusing the existing oil and gas structure.

Figure 12 compares the LCOH ranges for the above four hydrogen export cases to onshore steam methane reforming (SMR), steam methane with carbon capture, and electrolysis by wind or solar. The lighter green colored bars on the right for each of the project LCOH cases represent cases in water depths greater than 400 m. As can be seen from the figure, the project cases are all to the right of the onshore, with a significant cost differential to conventional hydrogen production through SMR and fossil fuel use. However, the gap is not as high when compared to hydrogen generated from low carbon energy. With a production or investment tax credit applied, the LCOH for offshore ROICE cases could potentially become competitive with onshore low carbon hydrogen. Having said that, it is not entirely clear if the other reference cases include applicable tax credits.

Figure 12: Levelized Cost of Hydrogen (LCOH) Comparison (\$/kg H_2) (Bartlett & Krupnick, 2020).

On examining all these comparative GSLCMaps and charts, similar conclusions can be drawn from comparing the LCOH cases as was done in comparing the LCOE cases:

- As expected, the range of LC for offshore renewable projects is higher than onshore renewables
- Hydrogen projects appear to be more competitive in the lower end of the LC range with onshore projects relative to equivalent power generation projects
- Repurposing helps reduce the LC for deeper water and/or far-shore locations
- Repurposing has a greater impact on small scale projects
- In several regions where repurposing does have a tangible impact, the overall LC is high even with repurposing, indicating challenging project economics

However, one unique conclusion for hydrogen generation cases is that levelized costs are similar for a wide range of project sizes. This would imply that small scale hydrogen projects with lower CAPEX outlays could provide similar returns on invested capital as larger projects. Therefore, a lead case for repurposing projects could be a small scale near shore hydrogen project.

As mentioned earlier, these are screening level estimates with generalized assumptions. More definitive conclusions are expected to be drawn in Phase 2 where ROICE designs will be developed for specific assets with more accurate cost estimates and include all applicable credits to estimate more accurate project economics.

Levelized Costs in BOEM Wind Lease Areas

As mentioned earlier, BOEM have announced three offshore Wind Energy Lease Areas in the Gulf of Mexico. The outlines of these can be seen below in Figure 13. An auction for these areas was recently concluded and the Lake Charles lease area was awarded to a bidder.

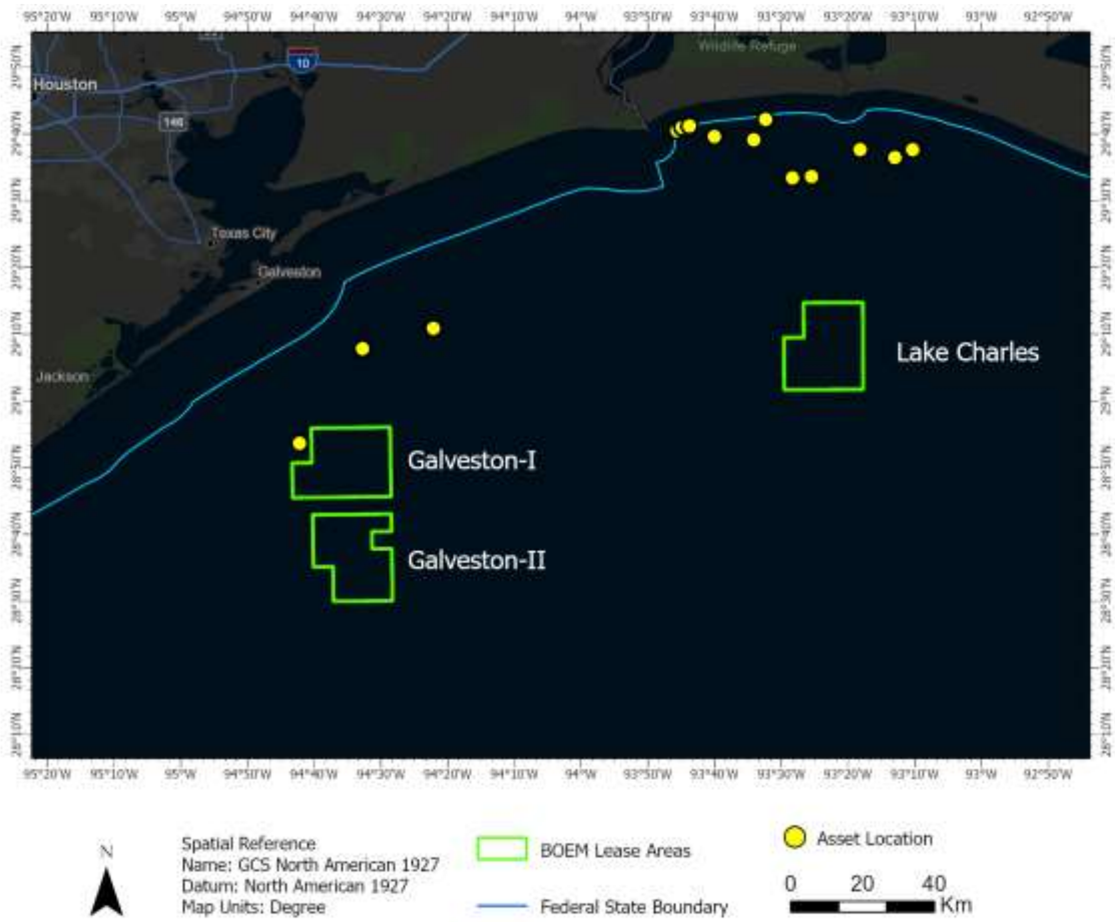

Figure 13: BOEM Lease area with nearby locations

Table 8 shows the average levelized costs for projects situated within these lease blocks for the eight different project configurations examined in this study. As can be seen, repurposing brings down the LC for all projects, but not significantly. No assets exist within these lease blocks, but several assets are in close proximity. These assets can be repurposed and connected to wind farms in the wind lease areas. Some of these assets will be studied in greater detail in Phase 2.

Table 8: LC Distribution over BOEM Lease Areas

Lease Blocks	E100N	E100R	E500N	E500R	H100N	H100R	H500N	H500R
	($/MWh)				($/kg)			
Lake Charles	142.7	138.9	118.2	117.3	6.65	6.44	6.33	6.28
Galveston-I	136.3	134.5	108.0	107.6	6.15	6.04	5.89	5.87
Galveston-II	153.2	150.4	115.6	114.9	6.45	6.30	6.18	6.14

Conclusion and Future Studies

A ROICE LC Model has been developed to estimate LCs for wind power and hydrogen generation for both new build projects and projects that repurpose some of the existing oil & gas infrastructure. Using this model, GSLCMaps have been generated that show LC distributions for different project scenarios across the GOM. These scenarios include new build and repurposed versions of wind and hydrogen projects at two different project sizes (demonstration scale and commercial scale). These GSLCMaps have been analyzed to identify favorable locations for ROICE projects, how they compare with onshore and other alternatives, and to understand the impact of various key variables and cost elements on LC.

Key Phase 1 conclusions are listed below.

- LCs for repurposed wind projects in the GOM range from $82 to $231 per MWh. Equivalent new build projects have LC's ranging from $82 to $437. LC's for repurposed hydrogen projects in the GOM range from $4.76 to $8.44 per kg of hydrogen. Equivalent new build projects have LC's ranging from $4.77 to $19.64.
- While noting that the above LC's do not include any federal or state incentives, these are higher than equivalent low-carbon renewables-based onshore projects, and even more challenged versus high-carbon alternatives.
- However, projects at the lower end of the range of LC's across the GOM have the potential to be competitive with onshore projects through efficient design, cost reductions and use of all available federal and state incentives.
- Of the different components of the oil & gas structure to be repurposed, it is probably most cost-effective to reuse the jacket (main support structure) and the deck (flooring above the structure) for ROICE projects. Pipelines can also be re-used to bring hydrogen back to shore. The remaining equipment will need to be decommissioned as per normal practice - removal of oil & gas topsides, abandonment of all wells and any pipelines that will not be used to transport hydrogen.
- Repurposing reduces CAPEX and shortens the schedule of implementation of ROICE projects, and it has a positive impact on LC for most projects. This improvement is more pronounced for deeper water projects and for smaller scale projects where the savings from reused infrastructure form a significant portion of the total project CAPEX - 5 - 10% for near shore locations and 25 – 60% for deepwater projects.
- It is advantageous to consider repurposing options for deeper water / further from shore projects. Of course, these projects are challenged with high LC's even after repurposing, so further optimization and greater production incentives are needed to make these projects attractive.
- CAPEX for hydrogen projects is in the range of +/- 10% of power project CAPEX. The incremental economics on the additional CAPEX for hydrogen generation is therefore likely to look quite promising in all cases, especially considering the healthier federal incentives for hydrogen production vs wind power generation.

In Phase 1 of this study, any federal credits such as ITC or PTC is not applied for renewable energy or 45V for low carbon hydrogen generation since these are likely to be project specific. Further, several broad assumptions have been made to generate LC's over a large geospatial area. More definitive conclusions are expected to be drawn in Phase 2 where ROICE designs will be developed for specific assets with more accurate cost estimates and include all applicable credits to estimate more accurate project economics.

The work scope for Phase 2 includes:

- Enhance the ROICE LC Model using advanced digital models
- Switch from Levelized Cost concept to project economic metrics such as NPV and Rate of Return
- Conduct sensitivity studies to see which parameters and scenarios have the greatest potential for optimizing and improving project economics
- Develop conceptual ROICE project designs for shortlisted assets using public domain information
- Work closely with ROICE workgroups to cross-implement findings
- Reach out to Operators and plan for collaboration on future phases.
- Refine the asset shortlist to identify potential demonstration and commercial project locations

Acknowledgements

The SHOWPLACE Research Team would like to acknowledge the support and guidance of many individuals and organizations:

- Subsea Systems Institute and TCEQ for their funding and support of Phases 1 and 2 of this work
- Dr. Ramanan Krishnamoorti for his support of this project in its early phases and guidance and advice throughout the course of this project
- XODUS Group (Elliot McDonald, James Monnington, Brendan Quinn) for providing the valuable base LC model and mapping grids, and training the team on the use of these tools
- “Super-Champion” SPC Members Aimee Thurlow (Enterprize Energy), Brian Gibbs (Endeavor Management), Elena Keen (Elena Keen Consulting), Paul Hughes (Subsea 7) and Brian Skeels (Technip FMC) for devoting significant time and effort to guide the project and building the external support networks
- SPC Members Ali Sims and George Morrison (Aquaterra), Ramone Nadira (Grid Advisors LLC), Luiz Soriano (Siemens Energy), Genevieve Saur (NREL), Robert Byrd (TSB Offshore), Stan Lueck (RODI Systems), Everett Anderson (NEL), Neil Kirby (GE), Jack Highberger (Hatenboer Water), Sujatha Kumar (DSIDER), Alex Zorniger (Power2H2) and Ashutosh Kak (Genesis) for liberally sharing experiences and valuable datasets that underpin the ROICE LC model
- Iiro Esko (Siemens), Andy Steinhubl (CHF), Joe Powell and Alan Rossiter (UH Energy) for their constant encouragement and vision
- UH Energy team – Sandra Bazan, Andy Chang, Deidra Perry, Emmanuel Juarez, Niurka Tamayo, Maria Banda – for all their behind-the-scenes administrative support for Phase 1 of SHOWPLACE

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